

REMARKS

Claims 1-16 and 18-39 are rejected, and claim 17 is objected to as being allowable if rewritten in independent form. Review and reconsideration on the merits are requested.

Claims 1, 5, 6, 10, 12-14, 16, 18, 20, 21, 23-28 and 30-39 were rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent 6,194,099 to Gernov et al in view of EP 858,119 to Nishimura et al. Gernov et al was cited as disclosing a carbon fiber electrode substantially as claimed, with exception of an impregnated solid polymer electrolyte. The Examiner relied on Nishimura et al as teaching the inclusion of a polymer electrolyte material in either or both electrodes so as to permit the smooth supply of lithium ions to the active material.

Claims 2, 7-9, 11 and 22 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Gernov et al in view of Nishimura et al, further in view of U.S. 2006/0035149 to Nanba et al.

Claims 4 and 15 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Gernov et al in view of Nishimura et al, further in view of US 2003/0049443 to Nishimura et al.

Claim 3 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Gernov et al in view of Nishimura et al, further in view of U.S. Patent No. 5,541,022 to Mizumoto et al.

Claim 19 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Gernov et al in view of Nishimura et al, further in view of U.S. Patent No. 6,085,015 to Armand et al.

Applicants traverse, and respectfully request the Examiner to reconsider for the following reasons.

Claim 1 is directed to a high-density electrode, obtained by impregnating a high-density electrode which comprises an electrode active substance and carbon fiber having a fiber filament diameter of 1 to 1,000 nm and has a porosity of 25 % or less, with a solid polymer electrolyte.

Each of the above rejections relies on Gernov et al as disclosing a carbon fiber electrode substantially as claimed, with the exception of an impregnated solid polymer electrolyte. In this regard, the Examiner was of the view that the limitation as to “a porosity of 25 % or less” would only represent a matter of optimization to the ordinary artisan. However, Applicants respectfully disagree. Rather, a characteristic feature of invention lies in its low porosity, and hitherto no conventional electrode for use in a secondary battery, having a porosity of 25 % or less, has been known. Further, as shown in detail below, Gernov et al discloses porosities substantially greater than 25 %, and contrary to the Examiner’s reading suggests higher porosity values.

Recently, not only high energy density per mass but also high energy density per volume is required of a secondary battery. In response to such demands, attempts are being made to enhance energy density per volume in an electrode or a battery by increasing electrode density and then increasing the amount of the electrode material charged in the battery container. By increasing the density of a battery, however, porosity inside the electrode decreases, which generally leads to problems such as a shortage of electrolytic solution present in the void space which is essential to electrode reaction and a delay in permeation of the electrolytic solution into the electrode. If the amount of electrolytic solution in the electrode is insufficient, electrode reaction is slowed and problems such as a decrease in energy density and high-speed charging/discharging performance and deterioration in cycling characteristics of the battery will arise. Also, if permeation of the electrolytic solution is delayed, the time for producing batteries is prolonged, which leads to an increase in production cost. (See Background Art).

In the invention of claim 1, by adding a specific carbon fiber to the electrode, permeability of the electrolytic solution does not significantly decrease even if the porosity is reduced to 25 % or less in a high-density electrode. The battery of the present invention also has

an effect (low resistance and good electrode strength) obtained by adding carbon fiber. By greatly reducing porosity and enhancing the density of the electrode, energy density per volume can be improved, and a reduction in permeability of the electrolytic solution can be suppressed. Thus, the present invention can avoid problems such as a delay in electrode reaction, a decrease in energy density and high-speed charging/discharging performance and deterioration in cycling characteristics of the battery.

Although addition of carbon fiber to a lithium secondary battery for the purpose of reducing resistance and improving electrode strength is known, it has not been known that the technique can contribute to suppression of reduction in permeability of electrolytic solution in a high-density battery.

Gernov et al (U.S. Patent No. 6,194,099)

The Gernov reference discloses adding carbon filaments to sulfur. The purpose of using carbon filaments in Gernov et al is, as described in col. 10, line 66 to col. 11, line 20 (reproduced below), to improve properties by ensuring a highly porous structure (emphasis in underline). That is, the Gernov et al teaches proceeding entirely opposite to the feature of the present invention, i.e., “an electrode having a low porosity”. Therefore, the present invention could not have been obvious, and there is no apparent reason to one of ordinary skill to reduce porosity to 25 % or less while Gernov et al teaches to the contrary.

Use of non-activated carbon nanofibers enables the solid composite cathode to have a highly porous structure which provides excellent access of the electrolyte to the electroactive sulfur materials, while also providing increased mechanical strength, increased electrical conductivity throughout the thickness of the composite cathode, adaptability for compression and expansion of the composite cathode during electrochemical cycling, ease of calendaring or compressing the composite cathode to a desired thickness without interfering with the desired access to electrolyte during tilling or cycling of the cells, and

increased adhesion to the current collector substrate and to any overlying layers, such as a coated layer to inhibit migration of cathode materials out of the cathode or a coated separator or electrolyte layer. Because electroactive sulfur materials, such as elemental sulfur and carbon-sulfur polymer materials, have poor electrical conductivity and generally very low porosity, it has been problematical to achieve the combination of excellent access to electrolyte and high electrochemical utilization while retaining or improving the desirable properties of electrical conductivity, mechanical strength, compressibility, and adhesion in solid composite cathodes utilizing electroactive sulfur materials.

In fact, the electrode density disclosed in Gernov et al is extremely low as compared with that of the present invention. Specifically, true density of sulfur is about 2 g/cm^3 and the true density of graphite is about 2.25 g/cm^3 . The electrode density values described in the Examples fall within a range of 0.1 to 0.55 g/cm^3 , even including the grid electrode of aluminum (true density : 2.70 g/cm^3). In the case where porosity is 25 % or less as in the present invention, the electrode density has to be 1.5 g/cm^3 or greater in terms of true density of sulfur. Thus, the present invention is clearly different in porosity from that of Gernov et al.

As for porosity, Gernov et al describes beginning at col. 2, line 60, as follows.

To achieve the highest possible volumetric density of the electroactive material in the cathode coating layer, it is desirable to maximize the weight per cent for electroactive materials in the coating layer, for example, 65 to 85 weight per cent for electroactive materials of a specific density of 2 g/cm^3 , and to maintain the porosity or air voids in the cathode coating layer as low as possible, for example, 40 to 60 volume percent. Particularly, the porosity of the cathode coating layer must be kept low because higher porosities, for example, 70 to 85 volume percent, do not provide enough electroactive material to obtain very high cell capacities.

Gernov et al neither describes nor suggests that as porosity or air voids are decreased, the amount of electrolytic solution becomes more and more insufficient. This in turn causes a delay in electrode reaction and problems such as a decrease in energy density and high-speed

charging/discharging performance. In the first instance, a porosity or air voids of 40 to 60 volume percent described in Gernov et al is very high as compared with the porosity value, 25 % or less, of the present invention. In such a range of high porosity, no problems such as shortage of electrolytic solution as mentioned above will arise. That is, the lack of such problem is further reason as to why one of ordinary skill would not reduce porosity to 25 % or less as required by claim 1.

As shown above, Gernov et al neither describes nor suggests a porosity of 25 % or less.

As described above, Gernov et al neither describes nor suggests that an electrode having good strength can be obtained by significantly reducing the porosity of an electrode (to 25 % or less) as compared with conventional electrodes without significantly decreasing permeability of electrolytic solution.

For the above reasons, it is respectfully submitted that the primary Gernov et al reference is fundamentally deficient, in that it neither discloses a porosity of 25 % or less and in fact suggests that higher porosity values, such as porosity value of 40 to 60 volume % as described in Gernov et al, are needed.

Nishimura (EP 858119)

Although the Nishimura reference teaches limiting the size of the phase separation of polymer alloy used in electrolyte to less than 100 nm, the reference has no description as to addition of carbon fiber or porosity of an electrode.

Moreover, the objective in the Nishimura reference is to suppress generation of lithium dendrite, which is not relevant to the present invention.

Therefore, Applicants respectfully question whether one skilled in the art would have been motivated to combine Nishimura et al with Gernov et al in the first instance.

However, even if combined, there is nothing in the cited prior which teaches or suggests a porosity of 25 % or less as required by the present claims. Moreover, because the prior art does not teach or suggest each of the claim limitations, and specifically a porosity of 25 % or less, it is respectfully submitted that the present claims are patentable over the applied prior art.

Withdrawal of the foregoing rejections and allowance of claims 1-39 is earnestly solicited.

In the event that the Examiner believes that it may be helpful to advance the prosecution of this application, the Examiner is invited to contact the undersigned at the local Washington, D.C. telephone number indicated below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

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